Experimental Study on Bendable Concrete

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Abstract: **Bendable Concrete commonly known as Engineered Cementitious Composite (ECC) is an ultra-ductile concrete with strain-hardening and multiple-cracking behaviour in tension and flexure. Over the last decade, enormous strides have been made in creating Bendable Concrete with extreme tensile ductility. In the present project strength characteristics of different Bendable concrete mixtures are evaluated by incorporating supplementary cementitious materials such as fly ash and reconfiber.**

In the present work bendable concrete is high in flexural strength compared with conventional concrete. In flexure, concrete is weak bendable concrete shows effective results on flexural values by partial replacing cement with fiber- recron fiber and flyash is partially replaced with cement by different percentages 10% 20% and 30%. The mix shows different strength for percentages of fly ash and dose of recron fiber in each mix

Keywords: Bendable Concrete, Engineered Cementitious Composites (ECC), Recron fiber

I. INTRODUCTION

Bendable concrete

Bendable concrete is ductile in nature. Under flexure, normal concrete fractures in a brittle manner. In contrast, very high curvature can be achieved for ECC at increasingly higher loads, much like a ductile metal plate yielding. Extensive inelastic deformation in ECC is achieved via multiple micro-cracks with widths limited below 60 µm about half diameter of human hair. This inelastic deformation, although different from dislocation movement, is analogous to plastic yielding in ductile metals such that the material undergoes distributed damage throughout the yield zone. The tensile strain capacity of ECC can reach 3-5%, compared to 0.01% for normal concrete. Structural designers have found the damage tolerance and inherent tight crack width control of ECC attractive in recent full-scale structural applications. The compressive strength of ECC is similar to that of normal to high strength concrete. Normal concrete is brittle in nature while ECC is ductile in nature, due to this property; it has wide applications & wide future scope in various fields.

ECC elongates without fracturing, due to the interaction between fibers, sand, and cement working in a matrix that binds everything together within the material. In addition to reinforcing the concrete with fibers that act as ligaments to bond it more tightly. The design of the cement matrix with special ingredients to make it more compatible with the fibers and to increase flexibility. Where ordinary concrete and fiber-reinforced concrete are designed to resist cracking, ECC is designed to crack only in a carefully controlled manner. The cracks that appear in ordinary concretes are griffith-type cracks; they increase in width as they grow longer. The cracks that are formed in ECC are steady state (or flat) cracks. The width of these cracks remains constant regardless of the length.

Need of the study

In the present experimental work, the ECC is prepared by the low modulus polyester group fiber in it. The performance of a low modulus fiber Recron 3S fiber is introduced in the Engineered Cementitious Composite ECC with suitable mix designs. Fibers in the cementitious matrix tend to reinforce the composite under all modes of loading and the interaction between the fiber and matrix affects the performance of cement based fiber composite material. Recron fibers are of polyester type which belongs to ester functional group. They exhibit strong interactions towards other polar substrates being polar in nature and because of this a very good bond is possible between fiber and cementitious matrix.

In the present paper, mechanical properties of recron fiber reinforced ECC under tension, compression, and flexure are studied, by testing different types of specimens., Cement/Sand ratio, fly ash replacement and fiber volume fraction will be studied under tension, compression, flexure type of loading.

Objectives of study

The objectives of the work is to prepare different nominal mix proportions by replacing cement with fly ash and by incorporating different volume of fibers. To compare the strength parameters of Bendable concrete samples with the parameters of conventional concrete . To compare the results of flexural behavior of the Bendable concrete with conventional concrete and comparison of bending phenomenon.

Scope of study

In the present study, the experimental study is conducted on bendable concrete. Fibers play an important role in bending of concrete. Recron fiber in bendable concrete shows an effective result when compared with conventional concrete. Bendable shows high flexural strength as water cement ratio decreases.

The strength of bendable concrete increases and fly ash improves the workability conduction for different doses of recron fiber. The total specimens 192 are carried out in this experiment

Notations:
BC-Bendable Concrete ;PCC-Portable Cement Concrete
ECC-Engineers Cement Concrete;

Experimental Analysis

In the present work, material characterization of Bendable concrete is studied. An experimental analysis was conducted to compare the mechanical properties of bendable concrete compressive strength, flexural strength, splitting tensile strength by replacing different percentages of fly ash and different percentage of fibers. A constant water/cement percentage for finding out better proportion for workability, while keeping the recron fiber volume fraction as 2%-3%, Super plasticizer as 2% and water/cement ratio fixed out as 0.5, and replacement of fly ash with cement is 20%-30%.

Recron Fiber

Recron 3s fiber was used as a secondary reinforcement material. It arrests shrinkage cracks and increases resistance to water penetration, abrasion and impact. It makes concrete homogenous and also improves the compressive strength, ductility and flexural strength together with improving the ability to absorb more energy. Use of uniformly dispersed recron 3s fibres reduces segregation and bleeding, resulting in a more homogeneous mix. This leads to better strength and reduced permeability which improves the durability Recron 3s prevents the micro shrinkage cracks developed during hydration, making the structure/plaster/component inherently stronger. Further, when the loads imposed on concrete approach that of failure cracks will propagate, sometimes rapidly.

Addition of Recron 3s to concrete and plaster arrests cracking caused by volume change expansion and contraction, simply because 1 kg of Recron 3s offers millions of fibres which support mortar/concrete in all directions.

Super plasticizer

Super plasticizer used is Conmix SP 1030. It is used to control rheological properties of fresh concrete. Super plasticizers are additives to fresh concrete which help in dispersing the cement uniformly in the mix. When used to achieve reduction in mixing water they can reduce water up to 15-20% and hence decrease W/C ratio by same amount. This results in increase in strength and other properties like density, water tightness.

Nominal mix design for Bendable concrete

As we are not using coarse aggregate in the Bendable Concrete, there is no separate mix design for the Bendable concrete. For this research we have to estimate the different mixes having different constituents which are Fibers and Fine aggregate Super Plasticizer.

Casting and curing of test specimen

In the detailed study about the Bendable Concrete or ECC to achieve workability and to know mechanical properties various trials have done as shown above. For each nominal mix, standard cubes 6 No's of size (150mmx150mmx150mm), 3 No's of standard prisms of size (100mmx100mmx500mm) and 3 No's of Cylinders (150mm diax300mm height) casted and cured using the accelerated curing tank & tested to know the strength. A total of 192 specimens were casted for all mixes which are having different proportion of Fly ash and with volume of fibers as 2% and 3%.

Mixing

Preparing a mix is having an important role in the concrete. In the preparation of ECC mixing is an important thing. It should mix thoroughly, before it is casted. As it is not having coarse aggregate in concrete the interaction between the fibres and other cementitious materials is based on amount of different constituents in concrete mix.

As the Bendable Concrete is different from normal concrete the mixing should be done in proper order to get a good workable mix.

In mixing we fallow a procedure for adding constituents to get a good workable mix all the dry material i.e. cements, Fly ash, aggregates, were added into drum and mixed thoroughly for 2-3 minutes. After that Water and super plasticizer was next added into dry material and mixed for 2-3 minutes. Recron fiber was added in last and mixed for an additional three minutes.

Flexural strength

Flexural strength is expressed in terms of modulus of rupture, which is the maximum stress at the extreme fibers in bending. It is calculated by flexure formula. After removal of the beam specimen from the curing tank, they are tested on the load frame of 20kN capacity in accordance with IS 9399:1679. The load frame is provided with two rollers at a distance of 400mm apart at the base. The load is applied through two similar rollers mounted at the third point of the supporting span spaced 133mm apart and centrally with the respect to the base rollers. The axis of the specimen is carefully aligned with the axis of the loading frame. The load is applied gradually without shock increasing continuously such that the extreme fiber stresses increase at a rate of 7kg/ sq.cm/min. i.e., application of load it at the rate of 4000N/min. the load is divided equally between the two roller points and it increased until the specimen fails. The load is measured by a load gauge (proven ring) mounted on top of the loading rollers the modulus of rupture is calculated for the maximum load taken by the member.

$$f_b = P \times l / bd^2$$

$$f_b = 3 \times P \times a / bd^2$$

Splitting tensile strength

The specimens were tested in accordance with IS 5816:1999. Specimens when received dry shall be kept in water for 24 h before they are taken for testing. Unless other conditions are required for specific laboratory investigation specimen shall be tested immediately on removal from the water whilst they are still wet. Surface water and grit shall be wiped off the specimens and any projecting fins removed from the surfaces which are to be in contact with the packing strips. The load shall be applied without shock and increased continuously at a nominal rate within the range 1.2 N/ (mm²/min) to 2.4 N/ (mm²/min). Maintain the rate, once adjusted, until failure. On manually controlled machines as failure is approached the loading rate will decrease; at this stage the controls shall be operated to maintain as far as possible the specified loading rate. The maximum load applied shall then be recorded. The appearance of concrete and any unusual features in the type of failure shall also be noted. In this test, a 150mm diameter by 300mm height cylinder is subjected to compression loads along two axial lines which are diametrically opposite. The load is applied continuously at a constant rate until the specimen fails. The compressive stress procedure a transverse tensile stress, which is uniform along the vertical diameter.

$f_t = 2\ P/(\pi \times l \times d)$

table 1

Slump test:

Cement/Sand Ratio	Percentage of fly ash replace with cement	Fibres Percentage (%) by Volume	Code Given for each mix	Slump values (mm)
1:0.5	30	2	BC1	35
		3	BC2	31
	40	2	BC3	42
		3	BC4	39
1:0.6	30	2	BC5	40
		3	BC6	35
	40	2	BC7	45
		3	BC8	41
1:0.7	30	2	BC9	34
		3	BC10	32
	40	2	BC11	35
		3	BC12	30
1:0.8	30	2	BC13	43
		3	BC14	40
	40	2	BC15	47
		3	BC16	45

The slump test is used for the measurement of a property of fresh concere. This test is an empirical test that measures the workability of fresh concrete. More specifically it measures consistency between batches. In the past for bendable concrete the slump measures as slump flow, due to its liquid form. But in this project we got slump values ranging from 31 mm to 47 mm. The results presented in above Table shows slump recorded during the test. According to the results, for different mixes of Bendable concrete the maximum slump was 47 mm and minimum slump was 31mm. From the results obtained we can observe the decreasing slump as the increasing volume of fibers in the mix. As the volume of fibers increases the mix is getting tough. The table shows for 30% replacement of flyash with cement the slump value is maximum at Cement/Sand ratio 1:0.8.Whereas for 40% replacement of flyash the slump value is getting maximum at Cement/Sand ratio1:0.8 where the low strength results are obtained. Table 4.1 shown below is having slump values which are obtained.

Compaction factor values:

Cement /Sand Ratio	Percentage of fly ash replace with cement	Fibres Percentage (%) by Volume	Code Given for each mix	Compaction Factor
1:0.5	30	2	BC1	0.91
		3	BC2	0.89
	40	2	BC3	0.93
		3	BC4	0.921
1:0.6	30	2	BC5	0.924
		3	BC6	0.91
	40	2	BC7	0.95
		3	BC8	0.93
1:0.7	30	2	BC9	0.916
		3	BC10	0.90
	40	2	BC11	0.913
		3	BC12	0.88
1:0.8	30	2	BC13	0.937
		3	BC14	0.923
	40	2	BC15	0.957
		3	BC16	0.944

Splitting tensile strength of Bendable concrete:

The splitting Tensile Strength indicates an increasing trend of tensile strength when fibers are added to concrete. Whereas for Bendable Concrete the strength is more when compared with PCC. In the above Table the variation of Splitting Tensile strength is shown. From figures we can see the variation of flexural strength with cement/sand ratios. In the Figure replacement of fly ash with cement as 30% there is a gradual decrease of splitting tensile strength from C/S ratio 1:0.5 to 1:0.8, and then maximum strength obtained at 1:0.5 C/S ratio. From the Figure we observe for mix BC 12 has more splitting tensile strength is obtained as 5.53 MPa. Here from the all figures we got an increasing splitting tensile strength for 40% replacement of fly ash with cement. From Figure when the volume of fibers is 2% there is noted strength obtained for C/S ratio 1:0.5 and fly ash replacement with cement is 30%.But from Figure for volume of fibers 3% the splitting tensile strength for

40% fly ash replacement is increased more for C/S ratio 1:0.7 as 5.53MPa. And from Figure the comparison between PCC and ECC (bendable concrete) mixes BC2& BC12 we can see a great increasing Splitting Tensile Strength compared to PCC.

Strength of Bendable Concrete:

Mix	Compressive Strength N/mm^2	Flexure strength N/mm^2	Splitting tensile strength N/mm^2
BC1	35.61	6.83	5.4
BC2	38.27	7.45	5.75
BC3	29.68	5.64	4.61
BC4	31.06	5.87	4.93
BC5	30.88	5.97	4.85
BC6	34.47	6.35	5.27
BC7	27.83	5.48	4.66
BC8	30.54	5.93	4.85
BC9	33.6	6.76	5.17
BC10	35.73	6.93	5.31
BC11	33.82	7.19	5.22
BC12	37.21	7.38	5.53
BC13	28.46	5.67	4.72
BC14	31.85	6.01	4.93
BC15	26.39	5.54	4.86
BC16	26.64	5.86	4.74

The experimental investigation shows that increase in volume of fibers from 2 % to 3% there is increase in strengths obtained. From all, mixes BC2 &BC12 has shown a greater compressive strengths, Flexural Strengths, Splitting Tensile Strengths compared to all mixes. And when compared to PCC there is a greater strength obtained for Bendable Concrete. From the Flexural strength the variation between PCC and Bendable Concrete is high, where Bendable Concrete shows greater Flexural strengths.

CONCLUSIONS

1.From the investigations, it is concluded that the Bendable Concrete with the mixes BC2 and BC12 are having best results and stated as best mixes when compared with PCC.

2. Fracture controlled failure is exhibited by the ECC under flexural loading, and a bend a bend is obtained because of crack controlling nature.

3. In the Bendable Concrete for the mixes having 30% replacement of cement with fly ash the best mix is BC2 which is obtained at Cement/Sand ratio 1:0.5 and having 3% volume of fibers.

4.In the Bendable Concrete for the mixes having 30% replacement of cement with fly ash the best mix is BC2 which is obtained at Cement/Sand ratio 1:0.7 and having 3% volume of fibers.

5. Workability aspect of Recron fibre reinforced ECC is an appreciable issue as satisfactory workability is observed with use of any chemical admixture with dosage of 1.5%

6. The Compressive strength of M30 ECC which is having 3% volume of fibre is greater when compared with 2% volume of fibre.

7. The Compressive strength of M30 Bendable Concrete is 16.4% greater in compressive strength than compared to M30 Nominal Concrete.

8. The maximum Compressive strength in Bendable Concrete having 30% replacement of cement with fly ash and having 3% volume of fibers is occurred at the mix BC2 as 38 MPa.

9. The maximum Compressive strength in Bendable Concrete having 40% replacement of cement with fly ash and having 3% volume of fibers is occurred at the mix BC12 as 37 MPa.

10. There is a great Flexural strength is obtained in M30 Bendable Concrete which is more than 100% when compared with M30 Nominal Concrete.

11. The maximum Flexural strength in M30 Bendable Concrete having 30% replacement of cement with fly ash and having 3% volume of fibers is occurred at the mix BC2 is around 7 MPa.

12. The maximum Flexural strength in Bendable Concrete having 40% replacement of cement with fly ash and having 3% volume of fibers is occurred at the mix BC12 as 7 MPa.

The maximum Splitting Tensile strength in Bendable Concrete having 40% replacement of cement with fly ash and having 3% volume of fibers is occurred at the mix BC12 is around 5 MPa.

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